HERITAGE 2016

5th International Conference on Heritage and Sustainable Development

BOOK OF ABSTRACTS

Edited by

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

green

HERITAGE 2016

Proceedings of the 5th International Conference
on Heritage and Sustainable Development
Volume 1

Lisbon, Portugal
12-15 July

Edited by

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

green lines institute
for sustainable development

HERITAGE 2016

Proceedings of the
5th International Conference on Heritage and Sustainable Development
Volume 1

Edited by
Rogério Amoêda, Sérgio Lira & Cristina Pinheiro

Cover photo: Terreiro do Paço, Lisbon (Photo credit: Tourism of Lisbon)

ISBN 978-989-8734-15-0
eISBN 978-989-8734-14-3

Published by
Green Lines Instituto para o Desenvolvimento Sustentável
Green Lines Institute for Sustainable Development
Av. Alcaides de Faria, 377 S.12
4750-106 Barcelos, Portugal
mail@greenlines-institute.org
http://www.greenlines-institute.org

1st edition, July 2016

Published in electronic format.

Print on demand.

Building heritage towards the future, through the energy efficiency

G. Loddo & D. Ludoni
Civil and Environment Engineering and Architecture Department, Cagliari University, Cagliari, Italy

ABSTRACT: In period of globalization, where real-time sharing of what happens in the world, opens each scenario to broader visions, even the concept of heritage acquires a significance far beyond. The current events in the Middle East are bringing in the foreground the blind fury toward priceless treasures of history, and they offer us a reason to reflect on the role and the new meanings attributed to historical heritage. The preservation of our heritage becomes a moral duty to society in that it finds the sense of humanity. Recovering a historic building, currently, means to follow a long and complex way that from the reuse of its function, necessarily involves the redevelopment of its envelope, both in terms of construction, energy efficiency, in order to adapt it to the current paradigms of sustainable. The trial travels on two parallel tracks: preservation and requalification. All design decisions must be taken to reduce energy consumption, CO_2 emissions and maintenance costs. Our research group has long been involved in studies on recovering of buildings located in the historic centre of Cagliari.

1 INTRODUCTION

It's known that the only historical value is not more enough to identify the inheritance that comes from the past. The heritage, regardless importance, has itself the value of humanity, of all humanity, and this meaning has an overall view of what man has built in the course of history, and it's valid in the West as in the East, and it represents the real capital of every human being The preservation of our heritage becomes a moral duty to society in that it finds the sense of humanity. Recovering a historic building, currently, means to follow a long and complex way that from the reuse of its function, necessarily involves the redevelopment of its envelope, both in terms of construction, energy efficiency, in order to adapt it to the current paradigms of sustainable. The proposed work concerns the primary school "A. Riva". The study proposes an energy upgrading of the envelope, assuming the replacement of existing windows with electrochromic glass, while maintaining the wall structure and composition of façades. Then the simulation studies the energy behaviour through the analysis in dynamic field. The building, of the first decades of the 20th century, still retains its original function, it has recently been subject of maintenance work of the façades, which are particularly valuable. The significance of this study includes many aspects that turn around the role of this building within the urban fabric. It represents a landmark in terms of planning, as a link between the historic quarter and the square that overlooks both the social function as multi-ethnic primary school for the neighbourhood, and specific activities related to the integration such as: courses for learning Italian language.

2 BUILDING HISTORICAL NOTES

In the course of just thirty years (1881-1911), Cagliari population has grown from 47,000 to 74,000 inhabitants. New inhabitants mostly settled in historic neighborhoods, occupying both still free areas and the superelevations of existing buildings. Until then all the schools had been housed in buildings adapted to the circumstances: the city did not have schools designed for this purpose. The growing demand for services was answered in 1896 with the decision to build four new buildings for primary education that were in line with the latest pedagogical trends. This paper concerns one of these buildings: the "Primary School Alberto Riva", located in the Garibaldi square of the Villanova historical district.

The design, in Medieval style, dates back to the first decade of the twentieth century, and it was a work by the engineers: Bartolomeo Ravenna, Dino Degioannis and, for finishing by Lorenzo Leone. The construction started in 1912 but works were stopped almost immediately (due the beginning of the War too). They restarted just in 1922, with the left wing and part of central block finishing. All works definitively completed only in 1930. Aerial bombing of World War II destroyed or damaged 75% of the city buildings: especially during those of May 13th, 1943, the school was badly damaged. The whole central block knocked down and it was rebuilt, according to the original plan, at the end of the war. The building, 1946-1950, was headquarter of the regional organization for the fight against the malaria, which, at that time, constituted a real health emergency.

Until '60 years the A. Riva school has probably been the most important and popular one in the city, in fact it housed more or less forty classrooms for a total number of over 1000 students a year. Since '70 years a slow decline began due to the depopulation of the historic centre up to definitive closure. From 2003 to 2011, much of the building was reconstructed thanks to the important works that involved the roof structural consolidation, façades maintenance and the adaptation to the safety rules.

The building is named after the young second lieutenant sharpshooter Alberto Riva Villasanta, born in Cagliari, gold and silver medal for military valour died on the Alpine front, November 4th, 1918, the last day of the World War I.

The building currently hosts, in the recovered block, twelve classrooms of the primary school with more or less two hundreds pupils. The number of immigrant children, mostly Filipinos and Pakistanis, became significant reaching over 10% of the total number.

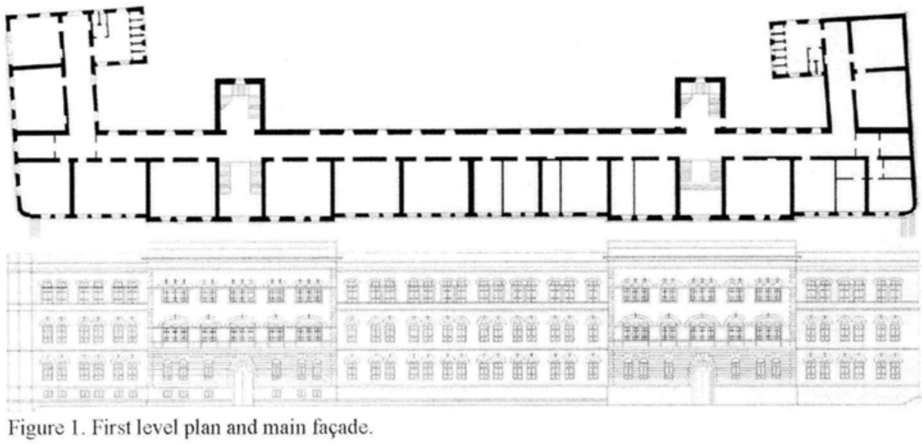

Figure 1. First level plan and main façade.

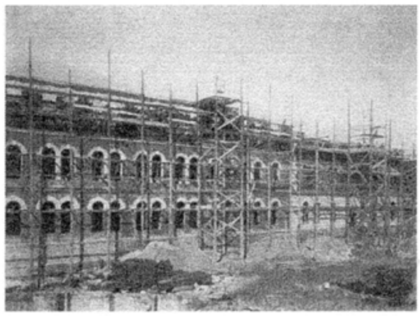

Figure 2. During construction.

Figure 3. End construction (around 1925).

Figures 4. After bombing of 13.05.1943.

3 GEOMETRIC AND CONSTRUCTION ASPECTS

The building occupies a rectangular site sized (124x38m) for an area of about 4700m^2. It has a U shape plan, with three sides facing the street and the fourth the rear court. The main façade, exposed to the South-East, is long about 124m, while those side, respectively facing North-East and South-West, measure about 28m each one, with a total linear development of 180m it represents one of the largest building in the city. The body of building is width an average of 12m, between the main and rear front there is a vertical drop of more or less 3m.

The building is composed by three identical levels above ground and, on the left, a basement area. The load-bearing wall structure is made of stone and brick, the intermediate floors are made of reinforced joists and brick layed in situ; the access stairs to the first level are a single symmetric ramp, while those to connect floors are three ramps.

The building is designed in eclectic style, with references to the Florentine Renaissance architecture in using mullioned windows and triple lancet windows, and in the rusticated ground floor finish.

The main façade is perfectly symmetric, with two slightly advanced blocks, in which the main doors are located. The three fronts facing the street, have a basement made of local stone (very close to the granite), in the advanced blocks, the covering is in limestone up to the first level, all the other surfaces are tiled with bricks; the rear, on the court, is simply plastered.

Openings, in three levels, are uniformly distributed and they are single light, mullioned a triple mullioned windows with calcareous ogival or segmental arches and moulding; capitals decorated with plant motifs. Openings of the rear front have rectangular shape; stringcourses and moulding are in limestone.

The frame of all openings, variously sized and shaped, is made of wood with a double clear glass pane, without darkening system, in the façade, facing the court, not yet restored, windows frame is made of wood with still a single clear glass.

Figure 5. Historical main façade.

Figure 6. Actual main façade.

4 ELECTROCHROMIC GLASS

EC glass are building glazing components that integrate chromogenic materials able to change, in a dynamic and reversible way, their optical characteristics as a function of the exterior environmental conditions or the interior comfort needs. This glass makes the best of fisical – chemical features of some materials able to change fisical state, from higly transparent to partially reflective. Particularly EC glass has inside multi-layers of materials, generally metallic oxide that changes chromatic characteristic as a function of the passage of a weak electric field. The production system takes advantage of nano-technologies to deposit a composite multi-layer film of metallic oxide and interposed between two clear glass slabs. These elements are than assembled with an inner laminated or tempered glass slab, which can be also low-emissive, 6mm of thickness, separated by a cavity, 12,7mm, filled with air or krypton gas; a sealing spacer for a total size of about 25mm. The activation of the electric field induces an oxidation-reduction reaction. This step produces a colour change in the film passing from fully clear state (state OFF) to the fully tinted state (state ON), thus preventing, in the state ON, to 97% transmission of visible light and 99% of incoming solar radiation, substantially varying the solar factor g (SHGC, Solar Heat Gain Coefficient) from 0,47 to 0,04. This change leaves the transparency of the glass slab so the visibility and the relation outdoor are preserved also when the glass is fully tinted.

The variation occurs in a period of time, ranging from three to ten minutes, in relation to the glass size and the condition and temperature at the boundary. The activation is manually performed with the use of a switch, or trough an automated system of building management and control (demotic system). The EC glazing are still expensive, but their high performance give hope for a greater spread them at a lower price in the future. The production offers a chromatic choice that, as a function of the metallic oxides used, is able to obtain, in the state ON, various colours as: blue, green and brown.

5 THE SIMULATION

The simulation was conducted, with the aid of the Modeling Software Design Builder that uses the module Energy Plus for the calculation of the building thermo-physical behavior, in the dynamic running. The base start of the simulation is modeling the geometric 3D envelope (Fig. 7). The representation has been simplified, given the complexity of the decorative elements in the facades, which, moreover, are absolutely irrelevant to the simulation. Then all the geometric characteristics and construction of building components are edited, such as vertical and horizontal closures, defining, in sequence: size and stratification of the materials that constitute them. The software, through the information entered, automatically calculates the thermo physical parameters, which are summarized in Tables 1 and 2 below.

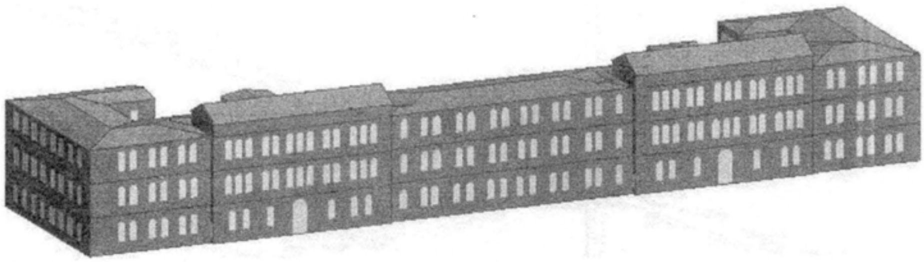

Figure 7. 3D Building model.

Table 1. Thermo-physical parameters of building components.

Component	Thick [cm]	R [mqK/W]	Usurf. [W/mqK]	U [W/mqK]
External wall	100.00	1.169	1.001	0.856
Internal partition	40.00	1.230	1.031	0.813
Roof	50.00	2.505	0.423	0.395
Ground floor	50.00	1.454	0.804	0.688
Intermediate floor	40.00	2.502	0.423	0.40

Table 2. Thermal parameters of glazing components in the current and simulation state.

Glass	Composition	SHGC factor	Direct solar transmission	Light transmission	U [W/m^{2}K] (EN 673)
Double clear Glass	(6-6) mm + 13mm Air	0.697	0.604	0.781	2.708
Double Electrochromic glazing	(6-6) mm + 13mm Argon	0.482 (state off), 0.04 (state on)	0.322	0.634	1.322
Double clear glass Low-e(only not exposed façades)	(6-6) mm + 13mm Air	0.562	0.474	0.745	2.40

The study has been conducted to reach the best performance in terms of energy saving, in this view, it decided using EC glass just in totally exposed façades. Instead for not exposed walls and not very occupied zones, such as toilets and storage rooms, it decided using double Low-e glass. The comparison is then evaluated between two cases: double clear glass, the current state and the EC glass, the requalification state. This is because EC glass, with their dynamic and changeable behaviour of thermo energetic features, represents the evolution and the overcoming of the double glass. The double glass, even if Low-E glass, are currently the most widely used, but they work in a static field and the value of their characteristics cannot change. The possibility to modify and modulating the glass behaviour, command according to the needs, makes the EC glass more useful and efficient. They can be effectively used both in Mediterranean area, characterized by long warm summer, and in areas with continental climate.

5.1 *The input data*

The function hypothesized for the building, is the same of the current state: primary education and extra scholastic activities. It is then sized the usual equipment as: pc, lighting, printing and weekly schedules of operation of heating and cooling system, in both two cases. In the simulation with the EC, has also been set the schedule time of activation within a week, for each month. The EC activation has been studied as a function of the sun chart evaluated for the latitude of Cagliari (Lat. 39°13') (Fig. 8), and the different orientation of the façades, to optimize the thermal features of the EC glass. Given the slight tilt of the building on North-South axis, it has chosen to give a half-hour overlap lighting the EC glazing on two adjacent façades.

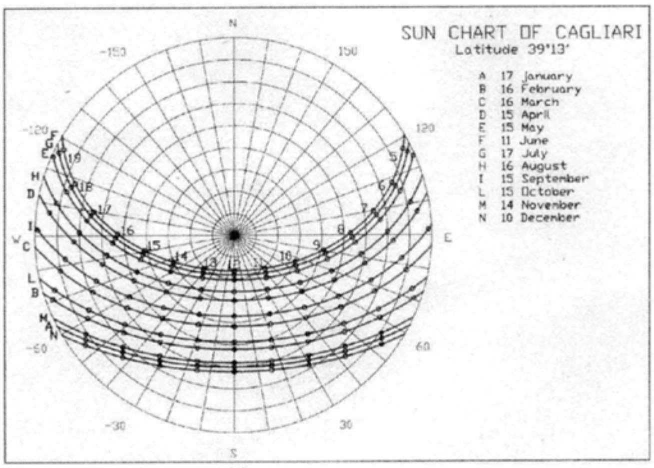

Figure 8. Sun chart (monthly average).

The simulation was set for a year, with monthly trend. In the current state, the heating system consists of radiators powered by a gas boiler; instead there isn't the cooling system. In the requalification case the same heating system has been repeated, and the cooling system has been set ex novo. The heating and cooling system activation is set in accordance with the National rules on energy savings. The tables below summarize the input data, on which the software calculates the energy behaviour in dynamic regime of the configured envelope.

Table 3. Heating schedule time.

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Sat	Su
Jan.-Marc	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	Off
Apr.-Oct.	Off	Off	Off	Off	Off	Off	Off
Nov.-Dec.	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	8,00-18,00	Off

Table 4. Cooling schedule time.

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Sat	Sun
Jan.-Marc	Off	Off	Off	Off	Off	Off	Off
Apr-Sept.	8,30-18,00	8,30-18,00	8,30-18,00	8,30-18,00	8,30-18,00	8,30-18,00	Off
Oct.-Dec.	Off	Off	Off	Off	Off	Off	Off

5.2 *The results*

Once completed the step of setting data, the program begins the simulation on the basis of the model configured, with reference to the climatic parameters relating to the locality. The results obtained are represented by tables which show the energy behaviour through some parameters, among which the most significant are: energy differentiated consumptions, solar incoming radiation intakes and CO_2 emissions. The graphic representation, at he same time, provides an immediate comparison of two simulations.

The study conducted has revealed that, in winter time, the EC glazing behaves, more or less, as the double and Low-e glass. With this premise, the analysis of the results has focused only on the data related to the summer time, because this is the most critic period in terms of the energy demand peaks to cooling, most of all in the areas with Mediterranean climate. Below is the summary table on solar incoming radiation (kWh), in two cases. Analyzing then the graph (Fig. 9), it is noted that in the EC glass case, the values, registered in summer period, are very lower than in the case of double glass, with a maximum Δ of 7027kWh in July.

Table 5 Intake of solar radiation [kWh].

Month	**EC** glass	**DG** glass	Δ [kWh]
January	16,938	13,577	3361
February	20,499	16,451	4047
March	32,622	26,355	6266
April	29,666	30,983	-1316
May	36,165	37,778	-1613
June	33,666	37,915	-4248
July	34,103	41,130	-7027
August	31,753	38,490	-6736
September	28,702	30,438	-1736
October	20,591	22,738	-2147
November	16,937	13,598	3339
December	13,802	11,012	2789
total	315,444	320,465	

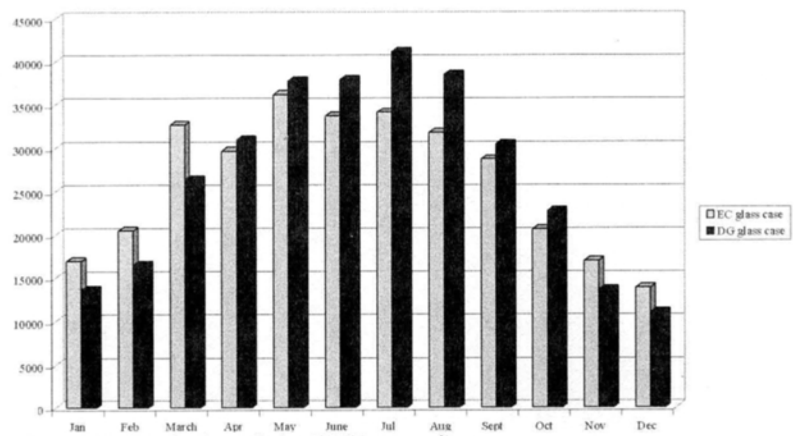

Figure 9. Intake of solar radiation [kWh] comparison.

This result is more evident if compared to the separated consumptions values, (Table 6). It is interesting to note that there are considerable variations as regards the consumption of energy used for cooling, in which the use of electrochromic glazing reduces the total value by about 60%, compared to the case of double glazing. From the analysis of the graph below (Fig. 10) and the Table 6, it's interesting to note that, it needs 22,716kWh to cooling with EC and 36,369kWh in the case of DG with a Δ of 13,653.

Table 6. Consumptions for cooling.

Month	Energy Cooling **EC** [kWh]	Energy Cooling **DG** [kWh]
January	0	0
February	0	0
March	0	0
April	0	0
May	783	1270
June	4255	7016
July	6107	9181
August	5055	8049
September	4744	7812
October	1772	3041
November	0	0
December	0	0
Total	22,716	36,369

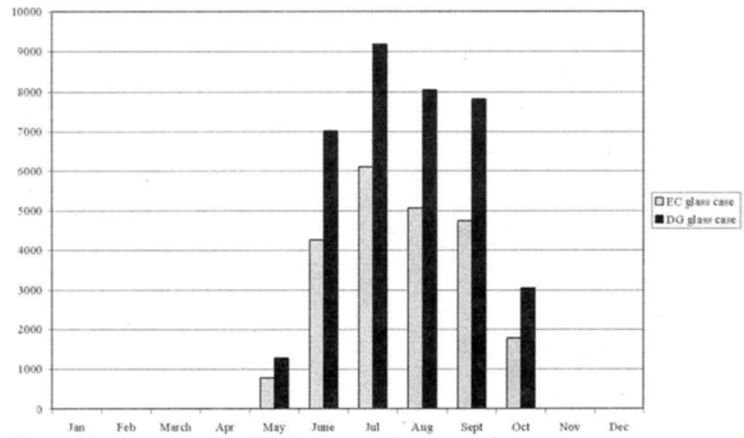

Figure 10. Energy cooling [kWh] consumption comparison.

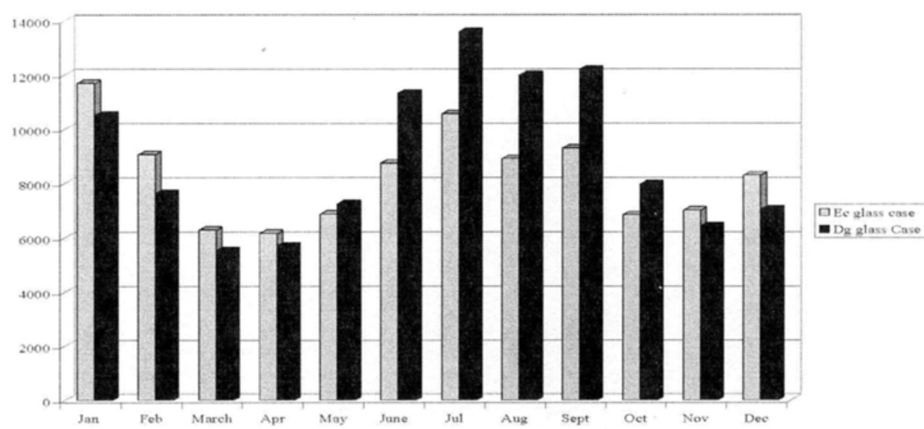

Figure 11. CO_2 emission comparison.

The lower energy required to air conditioning, produces a variable decrease of CO_2 emissions as it showed in the graph above (Fig. 11). This benefit is very important for the environmental sustainability and for the common objective to reduce global emission in the future.

Deepening the analysis, finally, the reduction of energy will be reflected positively in terms of costs, even if the EC technology is still more expensive than the traditional one.

The question of the unit price depends on the demand in the current market, which offers a wide choice of brands that provide good quality Low-e glass. The spread of the EC glazing is however still limited and therefore the price is still very high and different depending on the firm. Despite this aspect, we have to make some important arguments on the incidence of the price of glass per square meter of building surface, using EC glass rather than Low-e one. Another important factor is the discount that it may have on the full unit price in relation to the size of the order. The technology of low-emissivity glass is now well known in the current European market and clearly the unit price is very stable, but it can still be assumed that for an order of about 600m^2 (the total glazing surface of the building) the value can be 150€/m^2. For the same order the unit price of EC glass can be taken as 500€/m^2. Than the difference of the unit price is 350€/m^2, and for the total glazing surface, we have an increase of the total amount of 210,000€. Taking into account that the overall floor surface of the building is about 5,600m^2, the influence of the higher cost is less than 40€/m^2. Ultimately the increased spending, using EC glazing to upgrade the building is, in our opinion, acceptable compared to the advantages above mentioned.

In any case, beyond the economic evaluation, the primary objective is and remains the energy savings. Savings in terms of costs is, of course, an important corollary that descends from reaching the main objective.

6 CONCLUSIONS

The imperative of our times is: saving. This focus must be considered in a more wide view, both in energetic terms and all available resources. In this point of view the saving concept can be applied, all the more reason, to recover the historic building heritage that represents our memory. In order to reach this aim, we need to have technologies and materials related to them, that enable an efficient requalification of the historical building with light works not invasive, so as to preserve the original architectural elements, but in accordance with the rules of the sustainable architecture and the energy saving. Currently, after several study and simulation, we can state EC glazing represents the most versatile component able to make this.

This aspect is very important in the current urban landscape, where we are involved in the conversion of our built heritage. We know this operation is not easy, because it must preserve the original components, all decorative elements, external and internal. The use of EC makes it possible as it modifies neither the composition nor the shape of the envelope. It keeps unchanged still the whole wide view of the façades, as the EC glazing can be adapted to the various sizes of the openings.

The specific case, studied in this simulation, represents a good solution to achieve the primary objectives, above mentioned, for the future. The excellent thermal physical behaviour of the EC glass in the summer season, combined with their dynamic and reversible use allows optimizing the performances of the building envelope. These benefits more than offset the higher cost of the new technology, and also we must consider other aspects, not easily quantifiable, such as e.g.: the psychological well-being on users, induced by the best indoor comfort; the positive impact on the greenhouse effect, due to the lower CO_2 emission.

At the same time their apply permit to exploit the function of the edifice throughout the year, especially during the summer months, in fact at the end of school lessons, the construction may hosting various activities and aimed at the integration of non-EU community, more and more present in the neighbourhood. In Italy the educational buildings are closed for three months a year: from mid June to mid September, except some administrative offices included in the edifice. In this way a historical building, land mark for the citizens of Cagliari, became a tool of integration for the new inhabitants. In the light of what said, we think the inescapable targets for the future such as: energy saving and recovering of all already available resources, included the building heritage, must became priorities common to all mankind, without material and ideological borders, because we are housed in the same home: earth-planet.

ACKNOWLEDGEMENTS

The research team wishes to thank the various partners that have made their contributions possible up to now, in the various steps and phases of the study in progress: Bank of Sardinia Foundation (Fondazione Banco di Sardegna) and POR Autonomous Region of Sardinia (Regione Autonoma della Sardegna POR).

REFERENCES

De Forest, N., Shehabi, A., Garcia, G., Greenblatt, J., Masanet, E., Lee, E. S., Selkowitz, S. & Milliron, D. J. 2013. Regional performance targets for transparent near-infrared switching electrochromic window glazings. *Building and Environment*, n. 61, pp 160-168.

Della Mura, C. & Simonato Limena, E. 2012. *Architettura e nanotecnologie: small sizes, high performance*. Padova: Libreria universitaria.

Dyer, A. L., Bulloch, R. H., Zhou, Y., Kippelen, B., Reynolds, J. R. & Zhang, F. 2014. *Advanced Materials, A Vertically Integrated Solar-Powered Electrochromic Window for Energy Efficient Buildings*, pp. 4895–4900.

Lee, E. S. & Di Bartolomeo, D. L. 2002. Application issues for large area electrochromic windows in commercial buildings. *Solar Materials & Solar Cells*, pp 465-491.

Loddo, G. 1999. *Cagliari. Architetture dal 1900 al 1945*. Cagliari: Coedisar.

Loddo, G., Ludoni, D., Cossu, G. P. & Pittaluga, M. 2012a. Behaviour of Electrochromic Glass in the Mediterrean Area. In F. Bos, C. Louter, R. Nijsse & F. Veer (eds.), *Architectural and Structural Applications of Glass, Proc. Intern. Conf., Delft, June 2012*. Amsterdam: IOS Press BV.

Loddo, G., Ludoni, D., Cossu, G. P. & Pittaluga, M. 2012b. Multifunctional and Adaptive Architecture: Testing of Electrochromic Windows in the Mediterranean Climate. In IAHS (ed.), *Visions for the Future of Housing, Mega Cities, Proc. Intern. Conf., Istanbul, 16-19 April 2012*. Istanbul: IAHS.

Loddo, G., Ludoni, D., Cossu, G. P. & Pittaluga, M. L. 2013. Electrochromic glass: behaviour and energy saving. In GPD (ed.), *Glass Technology, Design and Sustainability, Proc. Intern. Conf., Tampere, 13-15 June 2013*. Tampere: GPD - Glaston Finland Oy.

Loddo, G., Ludoni, D., Pittaluga, M. & Cossu, G. P. 2012. Technologies of the future for the re-use of the past: the electrochromic glass. In R. Amoêda, S. Lira & C. Pinheiro (eds.), *Heritage 2012, 3th International Conference on Heritage and Sustainable Development; Proc. intern. symp., Guimarães July 2014*. Barcelos: Green Lines Institute.

Loddo, G., Ludoni, D., Pittaluga, M. & Cossu, G. P. 2014. Application of sustainable technologies in the future of historic buildings: electrochromic glass. In R. Amoêda, S. Lira & C. Pinheiro (eds.), *Heritage 2014, 4th International Conference on Heritage and Sustainable Development; Proc. intern. symp., Porto June 2012*. Barcelos: Green Lines Institute.

Masala, F. 2001. *Architettura dall'unità d'Italia alla fine del'900*. Nuoro: Ilisso.

Tucci, F. 2006. *Involucro ben temperato: efficienza energetica ed ecologica in architettura attraverso la pelle degli edifici*. Firenze: Alinea.

VV.AA. 1991. *Cagliari. Quartieri Storici. Villanova*. Cinisello Balsamo: Pizzi.

VV.AA. 1993. *Cagliari: una città che non volle morire*. Cagliari: Rotary International.